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(71) Applicant: Prokoski, Francine J.
Fairfax, Virginia 22030 (US)

(72) Inventor: Prokoski, Francine J.
Fairfax, Virginia 22030 (US)

(74) Representative: Ablett, Graham Keith et al
Ablett & Stebbing,
Caparo House,
101-103 Baker Street
London W1M 1FD (GB)

(54) Method and apparatus for annotation of medical imagery to facilitate patient identification, diagnosis and treatment

(57) A method and apparatus for annotation of medical imagery to facilitate patient identification. diagnosis. and treatment is characterized by an imaging device for producing a first signal representative of sensed characteristics of the individual and a minutiae generator which receives the first signal and produces a second signal representative of minutiae of the individual. the minutiae corresponding to specific branch points of blood vessels of the individual A minutiae data generator analyzes the characteristics of minutiae and produces a third signal representative of the characteristics which is stored in a minutiae database for each of the plurality of known individuals and their medical conditions. The minutiae and minutiae data may be used to annotate medical imagery to facilitate subsequent image comparison by providing standardized registration points and time-varying characteristics. A minutiae matcher pairs corresponding second signals and third signals from a current patient with those from a database record, and the paired signals are used to align the images and compare them. The minutiae analysis techniques of the invention can be used to identify medical patients. assist in the diagnosis of medical conditions. and detect and monitor the use of alcohol and drugs. including anesthesia.

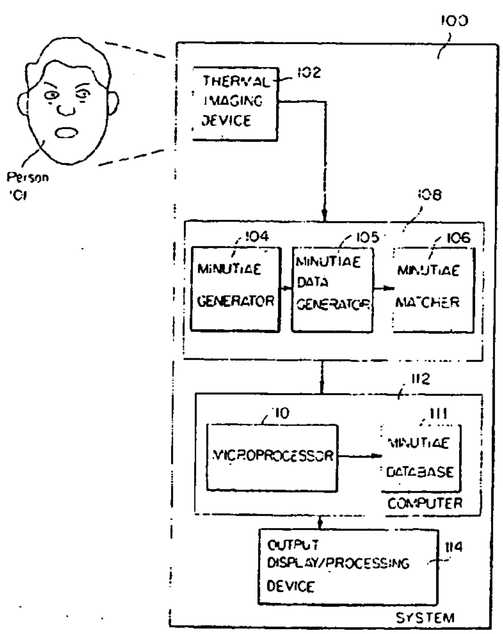

FIG. 1

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quality than the rolled prints, since inconsistencies in the amount of ink applied and in the pressure used to transfer the print to paper are not a factor.

Automated fingerprint matching techniques have been developed which rapidly classify an unknown print and then search through the portion of the database associated with that class looking for a match. Unknown prints may be from a "tenprint" card, or may be latent prints which have been lifted from a crime scene. A latent print may include a sizable area of one or more fingers, such as on a water glass, or it may include only a portion of one or more fingers, such as on a telephone keypad. Latent prints may be found on top of other latent prints, such as when several people have used the same telephone.

Matching techniques often extract minutiae points from the prints, and then compare the sets of minutiae rather than compare entire prints. Various classifications of minutiae types have been proposed by different companies and authorities. An example is given from the Costello U.S. Patent No. 4,947,443. Six types of"characteristic features" are presented in this patent, each one relating to a type of minutia. This fingerprint matching technique references the type, orientation, and location of each characteristic and each and every other characteristic. Using this approach, on the order of 80 to 150 minutia points are identified in each fingerprint. Other fingerprint minutiae extraction and matching patents produce essentially the same number of minutiae, with difference in what features of the set of minutiae are considered in attempted matching and in how the matching is performed. In U.S. courts, evidentiary rules have traditionally required that 16 or more minutia points be found to correspond between two prints in order for them to be considered to be from the same person. The determination of likely matching prints is generally assisted or performed entirely by a computer system; however, the final decree of a match is made by a fingerprint expert, who reviews the computer system results.

Matches between different prints taken from the same finger are never perfect, since the fingers are deformable, three-dimensional, connected and jointed structures which leave two-dimensional prints on surfaces they encounter through pressure. The exact angles between the fingers and the surfaces, the amount and direction of pressure, and the effect of movement between the fingers and the surfaces all cause variations in the exact prints produced. Even when prints are produced by a live scan technique, variation in the lighting, hand position, oil or dust on the fingers, use of lotions, and scratches or paper cuts will produce minor variations in the prints produced.

Therefore, the exact number, position, and characteristics of minutiae extracted from two prints may be different even though they are produced by the same finger. The challenge for an automated fingerprint identification system is to recognize allowable minor variations in actual matching prints while not allowing variations so wide that mismatches occur. Several AFIS products are now commercially offered which provide acceptable accuracy. Local and regional police forces may use smaller databases which contain only the prints of persons historically associated with their areas, rather than relying on federal resources to search the entire nationwide FBI files. Smaller scale fingerprint system, such as those associated with a system which controls access to an office building, may use the same minutiae matching techniques.

With rolled and live-scan prints, the orientation ofeach print, and the finger to which it corresponds is know. Also, quality checks can be built into the process such that repeat prints may be taken to insure quality when needed. In the case of latents, however, the analysis is done after the fact. It is not known which finger left the print, and the orientation of the finger may be in doubt when only a partial print is found. Therefore, matching of latents is much more difficult than matching of rolled or live scan prints.

Various minutiae extraction algorithms are used in current fingerprint identification systems, some of which merely utilize the location of the minutia points and others of which utilize also additional information about the type of minutia each point represents. For example, simple graph matching techniques can be used to compare the follow-the-dots vectors generated by connecting the minutia points in order forced by considering intersections with a spiral from the centerpoint of the fingerprint. Alternately, the ridge angle at each minutia point can be considered and matched along with the coordinates, in a best-fit attempt to match each unknown print to each known print. A measure of goodness of fit can then be computed and used to rank other possible matches.

U.S. patent No. 4,525,859 to Bowles teaches a pattern recognition system which detects line bifurcations and line endings, denoted minutiae, in a pattern of lines such as are found in a fingerprint. According to this reference, the FBI uses an automatic fingerprint identification system entitled "FINDER" which uses an optical scan reader. The information is then enhanced to eliminate grays and fill in gaps in the ridges. A 16x16 increment square window scans the fingerprint, an increment being a tenth of a millimeter. Thus, a window advances through the fingerprint in increments of tenth of millimeter and looks for ridges which enter the window but do not exit it. When such a ridge is identified, its coordinate location is stored and the ridge is analyzed to establish an angle, theta, of the ridge at the termination. The data are then re-scanned to look for terminations of valleys, which are ridge bifurcations. The additional coordinates and angles of each of the inverted ending points also are stored.

In latent prints, the distances between ridges of a fingerprint average 0.4 millimeters but can vary by a factor of 2 for any individual finger depending on skin displacement when the finger contacts the hard surface

are compared by computer to the set of vectors of known prints; and

Sixth, the comparison results are used to select potential matches and provide a goodness of fit indication between the unknown and known prints.

Numerous approaches to recognition using visible light imaging of faces have been proposed. Many of them apply standard pattern matching techniques: others involve definition of face metrics.

U.S. patent No. 4,975,969 to Tal discloses a method and apparatus for uniquely identifying individuals by measurement of particular physical characteristics viewable by the naked eye or by imaging in the visible spectrum. This reference defined facial parameters which are the distances between identifiable parameters on the human face, and/or ratios of the facial parameters, and teaches that they can be used to identify an individual since the set of parameters for each individual is unique.

Tal's approach utilizes visible features on the face, and therefore cannot be relied upon to distinguish between faces having similar visual features, for example as would be the case with identical twins. In addition, the "rubber sheeting" effect caused by changes in facial expression, the aging effects which cause lengthening of the nose, thinning of the lips, wrinkles, and deepening of the creases on the sides of the nose, all cause changes in the parameters and in ratios relied on in this method. Furthermore, the parameters and ratios of any particular person's face may be measured by anyone taking a photograph, and thereby used to select or disguise another person to appear to be that person. Therefore, the security provided by such a technique may not be adequate for unattended or highly sensitive locations.

Still another known scheme utilizes eigenanalysis of visual face images to develop a set of characteristic features. Pentland, View-Based and Modular Eigenspaces for Face Recognition, MIT Media Laboratory Perceptual Computing Section, Technical Report No. 245. Faces are then described in terms of weighting on those features. The approach claims to accommodate head position changes and the wearing of glasses, as well as changes in facial expressions. This disclosure teaches that pre-processing for registration is essential to eigenvector recognition systems. The processing required to establish the eigenvector set is extensive, especially for large databases. Addition of new faces to the database requires the re-running of the eigenanalysis. Accordingly, use of eigenanalysis may not be appropriate for use in a general face identification system such as would be analogous to the FBI's and AFIS fingerprint system.

Visible metrics typically require ground truth distance measurements unless they rely strictly upon ratios of measurements. Thus, such systems can be fooled by intentional disguises, and they are subject to variations caused by facial expressions, makeup, sunburns, shadows and similar unintentional disguises. Detecting the wearing of disguises and distinguishing between identical twins may be done from visible imagery if sufficient resolution and controlled lighting is available. However, that significantly increases the computational complexity of the identification task, and makes the recognition accuracy vulnerable to unintentional normal variations.

From the standpoint of evidentiary use, it might also be argued that the application of eigenanalysis to a very large database of faces, such as all mug shots in the FBI files, would be considered so esoteric by the public at large that automated matches based upon its use will not readily be acceptable to a jury as convincing evidence of identity. By comparison, techniques based on minutiae matching technique, such as are used with fingerprint identification, would be expected to find a more understanding reception by the law enforcement community, and to be more acceptable for evidentiary purposes within a reasonable number of years after their introduction.

One known scheme using facial thermograms for identification is described in the Prokoski et al U.S. Patent No. 5,163,094 which discloses defining "elemental shapes" in the surface thermal image produced by the underlying vascular structure of blood vessels beneath the skin. Depending on the environment of use, thermal facial identification may provide greater security over identification from visual images and may therefore be considered preferable. It is extremely difficult, if not impossible, to counterfeit or forge one face to look like another in infrared, whereas it is often possible to disguise one person to look like another in visible light. However, the use of elemental shapes is found in practice to be vulnerable to such variables as head rotation and tilt, ambient and physiological temperature changes, variations in imaging and processing systems, and distortions or obstructions in a facial image (e.g., due to eyeglasses).

Eigenanalysis of the elemental shapes of a thermal facial image has also been used for recognition. In one approach, several sets of elemental shapes are produced for each image by imposing different thermal banding constraints. The totality of shapes are then analyzed with respect to a library of facial thermal images. Eigenshape analysis is used to compare the characteristics of shapes in each person's images. Eleven characteristics of each shape are considered, including: perimeter, area, centroid x and y locations, minimum and maximum chord length through the centroid, standard deviation of that length, minimum and maximum chord length between perimeter points, standard deviation of that length, and area/perimeter.

Each person's image is then characterized by a set of 11-coefficient vectors. The difference in eigenspace between any two images is calculated to yield a measurement to which a threshold was applied to make a"match/no match" decision. In practice, such a system

Fig 13 illustrates the corresponding anatomy for the thermogram of Fig. 12;

Fig. 14 is a block diagram representing apparatus for maintaining the position of a surgical instrument relative to a surgical site according to the invention;

Fig. 15 is a facial thermogram of an alcohol-free individual;

Fig. 16 is a facial thermogram of the individual of Fig. 15 under the influence of alcohol;

Fig. 17 is a graph representing the thermal signatures of selected minutia points of an individual prior and subsequent to use of alcohol;

Fig. 18 is a block diagram of the apparatus for detection of alcohol and drug use by an individual according to the invention;

Fig. 19 is a graph representing the results of a statistical analysis of drug users in a random population; and

Fig. 20 is a block diagram of the apparatus for detection of alcohol and drug use in a random population.

DETAILED DESCRIPTION

Facial Minutiae Extraction

In Fig. 1, there is shown a system 100 for personal identification in accordance with the present invention. System 100 includes seven major subsystems: a thermal imaging device 102, minutiae generator 104, a minutiae data generator 105, minutiae matcher 106, minutiae database 111, microprocessor 110, and output display/processing device 114. In a preferred embodiment, minutiae generator 104, minutiae data generator 105, and minutiae matcher 106 are all implemented by program instructions stored in a program memory 108, and program memory 108, microprocessor 110, and minutiae database 111 are implemented by a programmed conventional computer 112.

In operation, thermal imaging device 102 obtains a thermal image of the face of person 101. A digital signal representative of the thermal image is provided as input to minutiae generator 104, which generates signals representative of thermal facial minutiae points for 101. These minutiae points have a number of characteristics including a specific location within the person or relative to other minutia, the apparent temperature at a given time, the temperature signature over a period of time, whether the minutia corresponds to a vein or artery, the width of the blood vessel, and the vector direction of branching blood vessels from the minutia. These and other characteristics are sensed and data relative thereto are generated by a minutia data generator 105. This data is stored in the minutiae database 111. The minutiae matcher 106 compares minutiae data for known individuals which has been stored in the database with that for unknown individuals currently being imaged by the imaging device 102. If a match is detected, a corresponding signal is sent to the output display/processing device 114.

In a preferred embodiment, output display/processing device 114 comprises circuitry to permit or deny access to a secured facility depending on the results of the matching performed by minutiae matcher 106. In one embodiment, access is permitted if the person 101 is recognized as one of a group of authorized personnel. In a second embodiment, access is denied if the person 101 is recognized as one of a group of unauthorized personnel. In yet another embodiment, access is denied if the person 101 is not recognized by system 100.

System 100 thus considers hidden micro parameter which lie below the skin surface, and which cannot be easily forged, if at all. The large number of such micro parameters considered renders it essentially impossible to search for a person to match another person's set of micro parameters. Furthermore, the particular infrared band used for imaging by thermal imaging device 102 may be kept secret, or multiple bands may be used, which further increases the difficulty involved in compromising system 100. The underlying features detected by system 100 are essentially "hardwired" into the face at birth and remain relatively unaffected byaging, thus providing for less inherent variability, than found in known recognition systems. Although thermal facial minutiae have some aspects related to, and extractable from, elemental shapes and may be tagged to reflect the elemental shape parameters (such as by tagging with fractal dimensions), minutiae extraction does not require production or consideration of elemental shapes. Furthermore, the comparison of thermal facial minutiae is computationally straightformard and introduces significantly less processing overhead than the known approaches used for template or shape comparisons.

Thermal imaging device 102 may be any device that produces a signal representative of the thermal characteristics of the face of person 101. In a preferred embodiment, a conventional digital video camera sensitive to thermal energy is used for the thermal imaging device 102. As described herein, it is found that tractable imagery for facial identification may be derived from passively obtained infrared images of facial heat emanations which can be detected by commercially available thermal imaging devices sensitive in the 3 to 12 micron wavelength band. Unlike fingerprints that are characterized by a limited range of intensity values corresponding to three dimensional ridges which are essentially concentric rings about a single center, plus anomalous arches, line endings, and bifurcations, facial thermograms are generally characterized by continuously varying

erator 104 next determines a vertical central line 208 perpendicular to eye line 206 and mouth area 205 and intersecting eye line 206 midway between left and right canthi centroids 201, 202. Minutiae generator 104 then determines a face center point 209 on central line 208 midway between the points of intersection of vertical central line 208 with eye line 206 and mouth 205. Minutiae generator 104 further determines a horizontal center line 210 perpendicular to the vertical central line 208 and passing through face center point 209. Vertical central line 208 and horizontal central line 210 are designated as face axes. Numerous other features may be used to define face axes, but in general it is preferable to define face axes based on areas of the face that are not greatly deformable.

Other techniques may be used for location of the face center point 209 in those cases where the preferred use of facial symmetry and recognizable thermal features does not suffice. For example, other techniques may be called for with respect to facial images in which an eye patch is worn, eyeglasses are not symmetrical, only a partial face is imaged, the lower face is covered or the thermal pattern of the face is unusually distorted. The face center point 209 may in fact be outside of the boundaries of the facial image, for instance where only a partial facial image is obtained due to the face being partially blocked by another face or some other object. If the person 101 is wearing glasses, the pattern of the glasses, which typically block the infrared emissions from the face and thereby produce an extended cold area with sharp thermal discontinuity, can be used to determine approximate face axes. Additional techniques include manual location of the face center point 209 and preprocessing using known techniques to locate the approximate area of the face center point 209. As described below the face axes may be tested for validity to determine whether the image requires any such special treatment.

II. Testing the Validity of Face Axes

Since the known techniques for identifying left and right canthi centroids 201, 202, left and right nostrils 203, 204, and mouth area 205 are subject to artifacts and other sources of error, and since some images of faces are significantly asymmetric or have features that are entirely missing (e.g.,due to person 101 wearing an eye patch or having a disfigured face), minutiae due to person 101 wearing an eye patch or having a disfigured face), minutiae generator 104 performs checks to help spot instances where these points may have been incorrectly located or where unusual facial images are encountered. First, a check is made to ensure that vertical central line 208 and mouth line 207 intersect within mouth area 205. Next, a check is made to ensure that vertical central line 208 intersects a line connecting left and right nostrils 203, 204 at point between left nostril 203 and right nostril 204. If either of these conditions is not met the face is considered to be a special case calling for manual intervention to determine the best approximation for face axes.

III. Normalization

In practice, it is found that preprocessing through normalization of image size provides advantages in later recognition. Accordingly, minutiae generator 104 uses the distances between left and right canthi centroids 201 and 202 and the distance from face center 209 to eye line 206 to compare the size of facial thermogram 200 with a standard image size. In a preferred embodiment, linear correction in the vertical and horizontal dimensions is used to normalize the size of facial thermogram 200 to match the standard, but other normalization models could be used as well.

IV. Production of Thermal Contour Lines

As provided by thermal imaging device 102, facial thermogram 200 consists only of an ordered list of thermal values corresponding to each small portion of the imaged face. Minutiae generator 104 employs the following procedure to produce thermal contour lines for facial thermogram 200:

a. For a digitized image having N bits of resolution, or 2^N bands of thermal values, determine thermal contour lines having a particular "current" one of the 2^Nvalues.

b. Produce minutiae in accordance with the steps below for the contour lines of the current value.

c. Repeat a and b above, each time using new one of the 2^N values for the "current" value, until the desired number of minutiae have been extracted of all of the possible values have been processed.

d. If the desired number of minutiae have not been extracted, repeat the process beginning with 2^{N-1} bands of values, and reduce the number of bands by 1 with each iteration, skipping those that are powers of 2, until the desired number of minutiae have been extracted or until no further reduction in bands can be achieved.

Various other techniques for generating contour lines may also be used, with the goal being obtaining a sufficiently large number of minutiae for unique recognition, without producing too many spurious minutiae. Spurious minutiae increase processing overhead without benefitting recognition. The number of thermal bands that will produce an appropriate number of minutiae is readily determined by trial and error for any particular application of system 100.

vides an additional advantage of compressing the data used for recognition.

The wide variety of techniques for generating minutiae described above provides an added measure of security, as one attempting to mimic thermal facial minutiae may be able to do so if one technique for generating minutiae is used by minutiae generator 104, but not if another is used. Thus, without prior knowledge of the particular technique being employed by minutiae generator 104, system 100 becomes even more difficult to comprise than it otherwise might have been.

As mentioned above, it may be desirable that all thermal images be scaled to a standard size prior to processing. It also may be desirable, depending on the thermal imaging system used, that all thermal images first be normalized to a standard thermal profile before processing. In alternate embodiments, intended for various applications and various environments, these preprocessing steps may significantly increase accuracy in recognition or may merely impose unnecessary processing overhead. For example, if system 100 is used in connection with an outdoor automated teller machine, thermal normalization may be needed to deal with seasonally wide variations in surface skin temperature.

Minutiae Matcher 106

As mentioned above, minutiae generator 104 and minutiae data generator 105 are used to produce minutiae data signals for a population of known persons. The data corresponding to these signals are stored in minutiae database 112. Thermal imaging device 102 then obtains a thermal image of an unknown person 101 and minutiae generator 104 produces signals representative of the minutiae and minutiae data generator 105 generates data for the minutia for that person. Once these signals have been produced, minutiae matcher 106 compares the signals representative of person 101 to signals from minutiae database 102 corresponding to minutiae data of known persons. In a preferred embodiment, minutiae matcher 106 performs three basic functions to obtain a match: alignment of the unknown face, comparison of minutiae data, and selection of a match. Each of these functions is described in greater detail below.

I. Alignment of Unknown Face

Because there may not be control over the position of the face of person 101 with respect to the field of view of thermal imaging device 102 when image is obtained, the orientation of the face may not be such that the facial axes are aligned to be horizontal and vertical. Thus, minutiae matcher 106 corrects the orientation by rotating the image such that the facial axes are horizontal and vertical. Next, conventional processing using a three dimensional model is applied to correct for any rotation or twist of the head. In a preferred embodiment, such processing models the head as a sphere with a diameter equal to the apparent width of the face, and anti-distorts the image to provide a view which is normal to a surface plane across the forehead and upper lip and in which the center of the sphere coincides with the face center. In a conventional manner, the nose and chin are ignored so as not to disrupt positioning of this surface plane.

II. Comparison of Minutiae

Comparison of the minutiae data of the unknown person 101 with minutiae data from known persons begins by comparing locations of such minutiae. First, the locations of minutiae for a known face are considered, and denoted as M(K)i. Next an allowed positional error ε is selected, as is determined to be appropriate for any given environment in which system 100 is used. The minutiae of the known face are then overlaid on the minutiae of the unknown face, denoted M(U)j. Any M(U)j that are not with ε of one of the M(K)i are ignored. Any M(K)i which are not within ε of on the M(U)j are ignored. This leaves a residual set of minutiae pairs. If this set is empty, there is not a match between the two images. Otherwise, the characteristics of the corresponding points are compared.

Depending on the application, any comparison technique that considers the characteristics (x, y, z, α, R, B, T) listed above may be used to generate a comparison metric. In a preferred embodiment, only the positional differences are considered.

The simplest decision technique is to set a minimum number of pairs of corresponding minutiae for a potential match. If an unknown face and a known face exhibit a least the minimum number of corresponding minutiae pairs, they are considered to be a potential match.

In an alternative embodiment, the Δx and Δy values for each pair of corresponding minutiae are determined, and the distribution of Δy with respect to Δx is then determined for the overall set of minutiae pairs. The standard deviation of that distribution is then compared against a threshold standard deviation to determine whether a potential match exists.

In still another technique, a new error measure ε' is introduced dependent not only on location but on thermal value (z). Minutiae pairs are only considered if they are within a certain thermal value difference Δz as well as have locations within the distance error ε, thereby satisfying new error measure ε'.

Further levels of decision requirements can similarly be added to produce the desired level of confidence in the match for the application at hand. Each possible comparison of the unknown face with known faces is performed, and then the known images are rank-ordered according to the goodness of fit (e.g. closeness in metric) with the unknown face.

number of type A and type C cells. If a face is divided in to 36 grid cells as illustrated in Fig. 6, classes could be designated as nAmC, where n is the number of type A cells m is the number of type C cells, n+m = 36 - p and p is the number of B cells. Using this arrangement, 1260 classifications are possible. Alternatively, ranges of values can be considered to be within the same class.

As a further refinement to such classification, the degree of bilateral symmetry in distribution of type A cells and type C cells could be considered. If the face is divided into four quadrants designated upper right, lower right, upper left, lower left, each quadrant having 9 cells, a metric for classification could look at differences in the numbers of type A and type C cells in horizontally or vertically adjacent quadrants. Such metrics may be the absolute difference in minutiae between such quadrant pairs, or may be simplified by merely indicating whether a left (or upper) quadrant has more, fewer, or equal minutiae as a corresponding right (or lower) quadrant.

Other possible classifications are based on geometric values of, and ratios among, the points and lines described in connection with Fig. 4, once the face has been normalized as described above. In some applications, a combination of visual and thermal attributes may be employed for classification. For example, a ratio between the distance between left and right canthi centroids 201, 202 in facial thermogram and the distance between the left and right pupils as determined through visual imaging is found to be a useful metric for classification, as is the ratio between the distance from eye line 206 to horizontal central line 210 and the distance from a line connecting the eyes to the tip of the nose as determined by visual imaging, as is the ratio between the distance between left and right nostrils 203, 204 and the distance between the outer limits of the nostrils as determined by visual imaging.

The usefulness of facial thermal imaging in recognition applications is increased by appropriately encoding thermal facial images so that consistent codes are generated each time a facial thermogram of a person is obtained. Such a coding scheme reduces database search and minutiae matching overhead, thereby allowing faster processing using less expensive equipment. In a preferred embodiment, overlaying a grid on a face such that 144 cells cover the area of the face, and assigning a binary code to each cell, such t hat the cell is encoded with a "1" if the cell contains one or more minutiae and "0" if the cell does not contain any minutiae, is found in practice to yield good results. Since this encoding scheme preserves the relative location of each bit, it is straightforward to ignore selected bits in cases where only a portion of a face is imaged, due to obstruction, disguise, or orientation.

Use of such a "facecode" also facilitates straightforward verification and comparison techniques. In some verification applications, for example, a requirement that 10% of the coded bits match may be considered sufficient to provide a desired level of confidence. Simple difference comparison on a bit-by-bit basis, which is computationally extremely efficient, is sufficient to determine the number of corresponding bits between a code of an unknown face and that of a known face. Where multiple known faces exceed a threshold level of similarity, the one with the greater number of common bits is readily selected as a best match.

Although the discussion above has been directed to thermal images of faces, it should be recognized that similar techniques and systems may readily be applied to images of other body parts in accordance with the present invention. It should also be recognized that numerous other imaging modalities besides thermal imaging may be employed in accordance with the present invention, for example x-ray, NMR, MRI, and CAT scan imaging. It should also be recognized that known schemes for pattern recognition and graph matching may be applied readily in accordance with the present invention, depending on the needs of a particular application.

Standardized Infrared Minutiae Co-ordinate System (SIMCOS)

The method and apparatus described above for facial minutiae extraction can be used to develop a standardized minutiae co-ordinate system for identification of medical patients and for diagnosis of medical conditions. Because an infrared camera operates at a distance from the patient and detects and records only radiant heat spontaneously emitted from the body surface, it constitutes a painless, non-invasive, passive method of recording patterns of body surface temperatures. These patterns have been found to depend upon the underlying vascular structure and are unique for each person. Infrared identification therefore provides a method for uniquely identifying individuals under all lighting conditions, including total darkness. It is not prone to forgery or multiple identity deception and so provides convenient and highly secure identification of individuals. The method for generating repeatable registration points on the skin surface of the human body utilizes discrete minutiae points obtained from the thermal images. Visual characteristics of the body, such as size and shape and relative position of body parts, are maintained in the infrared image. In addition, the details of the vascular system are indicated by the distribution of temperature across the skin surface. Current infrared cameras are sufficiently sensitive to temperature variations that they clearly distinguish the skin directly overlaying blood vessels due to the thermal difference caused by the flow of warm blood. The vascular structure appears as a white (hot) overlay of the circulatory structure on top of a grey scale image of the thermal map of the body, as shown in Fig. 7.

In Fig. 8, there is shown apparatus 100a for processing infrared images to yield repeatable minutiae

cially-available thermal imaging devices sensitive in the 3 to 5 or 8 to 12 micron wavelength bands. Images are this type are shown in Figs. 7. 10. 12. and 13.

Current infrared cameras produce a standard analog or digital output providing 30 frames per minute as shown in Figs. 7-10. Tracking the minutiae from frame to frame assists in the exploitation of the dynamic IR imagery by allowing measurements to be made over time from the same body locations while accommodating changes in position due to respiration, voluntary or involuntary movements of the subject, and intentional or accidental variation in the position of the imaging system. The use of infrared video imagery also allows the imagery to be recorded in real time for later analysis. and provides a self-documenting chain of custody identification of the person recorded, all without the necessity for the cooperation of the person being imaged.

Infrared imaging can be used to locate minutiae points over the entire body surface which correspond to intersection points and branch points of the underlaying blood vessels. This provides a built-in set of registration points on the body's surface. which can be annotated onto images produced by any medical sensor used in conjunction with the thermal imager. The registration points then can be used to compare and combine medical images taken with different equipment at different times and under different conditions, facilitating comparison of those images. Also, the minutiae points provide reference points for continuous re-alignment of surgical instruments, radiation sources. and other diagnostic or treatment equipment. Since the infrared camera is totally passive. it can be used continuously during other medical procedures to overlay precise registration points on the other images while also monitoring for overheating, shock, hypothermia, renal failure, and other medical conditions. At the same time, the pattern of minutiae points superimposed on each image provides positive identification of the patient. Such applications are of particular importance during telemedicine procedures.

The normal body is basically thermally bilaterally symmetric. Side to side variations are typically less than 0.25 degrees Celsius. This fact is used in assigning axes to the body's image. Where the skin surface is unbroken. there is gradual variation of temperatures across blood vessels, with the highest temperatures across the body surface being directly on top of major blood vessels. Major thermal discontinuities occur at entrances to body cavities such as the eye sockets, nostrils, or moth. These provide global reference points for automatic orientation of the thermal image. Local and relatively minor discontinuities in the skin surface occur at scars, moles. burns, and areas of infection. The thermal surface can be distorted through pressures and activities such as eating, exercising. wearing tight hats and other clothing. sinus inflammation. infection, weight gain and loss. and body position. However. the minutiae points remain constant with respect to their position relative to the underlying blood vessels.

The technique for thermal minutiae extraction and matching can be summarized as follows:

1. Current thermal image is digitized.

2. Current image is divided into pixels, where the size of the pixel relates to the resolution or quality of the result desired.

3. Certain pixels are selected as minutiae points.

4. Each minutia is assigned a vector having magnitude and directional information in relation to the surrounding characteristics of the thermal image. Additional characteristics, such as type of minutia may also be recorded for each. Typically for each whole body thermal image, there would be on the order of 1200 minutiae.

5. Set of minutiae vectors of the current image are compared by computer to the set of vectors of other images.

6. Comparison results are used to determine corresponding minutiae from the two images and to morph or mathematically adjust one image with respect to the other to facilitate comparison.

7. Differences between the current image and database images are computed for either the entire image or for areas of interest.

It is desirable that all thermal images in a database be normalized to a standard thermal range and be scaled to a standard size during search and comparison procedures. Both normalization and scaling eliminate some minute amount of identifying characteristics of a particular person or his condition. However. the standardization procedures greatly aid in the exploitation of the database by reducing the need to calibrate every imaging sensor used to produce images which will be filed in, or compared to database images. For example, in accident triage with no accurate ground truth reference in the scene and possibly use of inferior quality imagers, standardization to constant size and thermal range is appropriate in order to match against database. Furthermore. standardization facilitates use of simulated imagery for telemedicine and telesurgery applications. For example, when incorporated into the military's automated battlefield medical pod, real time normalized thermal minutiae can be used to properly position injections and application of external pressure to stop bleeding.

In addition. standardizing database images facilitates comparison of imagery during growth from childhood to adulthood. compilation of medical libraries of images from large number of people. and automated com-

are both already using electronic images as well as x-rays and medical records. Laparoscopic surgery is an electronic form of surgery. Teleradiology, telepathology, and teleconsulation are already, widely accepted electronic medical practices.

As telemedicine and telesurgery become more common, there will be more potential for error in identification of patients and the treatment to be performed, and more need to document the precise medical history and treatment procedures performed by a given doctor on a given day. Filing, recall, and comparison of documentation collected over time by different sensors at different facilities will need to be automated to a greater degree, while protecting the privacy of the patients. The identification technique of the invention offers a low-cost, repeatable, non-invasive, passive system for standardization and registration of many current forms of medical imagery, while also offering an approach to high security maintenance of files with immediate access in emergency situations.

Identification of Drug and Alcohol Usage

Many drugs, including cocaine and alcohol, are vasoconstrictive substances which cause cooling of the skin surface. the resultant cooling is detected through passive imaging of the thermal energy emitted form the face. In Fig 15 is shown the thermal image of an individual who is substance free and in Fig. 16 is a thermal image of the same individual after the ingestion of alcohol.

The thermal imaging techniques of the present invention can be used to detect substance use by individuals, even where the individuals's identity is unknown. This is accomplished by compiling databases of statistical analysis of thermal signatures obtained from clinical trials in which cooperating subjects have concurrent drug testing performed using urinalysis or blood testing along with thermal signatures obtained from known subpopulation but without concurrent testing by other means.

The vascular system supplying the human face typically exhibits thermal variations on the order of 7°C across the facial surface. Certain general features, such as hot patches in the sinus areas, relatively cool cheeks, and cold hair pertain to all facial thermograms. Other features such as specific thermal shapes in certain areas of the face are characteristic of a particular person. Measured disturbances to other features, such as the general symmetry between two sides of face, range of thermal variations in the forehead, peak temperature, size of canthi pattern, and variations in those disturbances over time, may be correlated with a high probability of drug or alcohol use.

Variations in temperature across the facial surface can be imaged by thermal cameras sensitive to wavelengths in the 3-5, 8-12, or 2-15 micron ranges. Current cameras can provide thermal resolution better than 0.07°C and spatial resolution of better than 02°; resulting in 65.000 to 265.000 discrete thermal measurements across the surface of the face. For most such cameras, that thermal map is regenerated 30 times per second to produce either a standard video output which can then be recorded and processed on standard videotape equipment, or a direct digital signal which can be immediately input to a computer.

Certain drugs appear to produce characteristics features in facial thermograms, which may be identifiable from detailed analysis of the structural patterns and distribution statistics. Furthermore, the rate of change at any point in time may be a discriminator between chronic and recent use of each drug. Using currently available thermal imaging cameras, thermal signatures emitted from the face can be used to deduce changes in activity levels of specific arteries in the brain which are known to be affected by particular drugs.

The vascular system has a common structure in each person, with known pathways for instance from the heart to the brain, and known pathways between blood vessels in the face and those in the brain as shown in Figs. 2b and 2c. Using the SIMCOS technique, a set of standardized minutiae appearing in the face can be identified. Through clinical drug trials using known types, amounts, purity, and administration techniques, the thermal effects over time at each such minutiae location can be observed. The effect of varying the type, amount, or purity of drug can also be observed. The effect on different people can be observed. Since the thermal effects may be quite small and localized, it is important to utilize the SIMCOS method for identifying the precise minutiae locations in each subject. That provides repeatability of measurements over time without requiring the application of registration markers to the face, or the use of invasive techniques to repeatably find the same locations. Also, it provides a method for comparing corresponding locations in different subjects.

Statistical analysis of time-varying thermal signatures at each facial minutiae point before, during and after drug or alcohol administration provides a reference dataset which represents the thermal effect of that substance under the protocol used. A library of thermal minutiae substance effect signatures can be developed for various drugs and other substances for which screening is desired, including for prescription and over the counter medications, tobacco, and alcohol. Fig. 17 presents an illustration of thermal signatures associated with substance-free subjects. These may differentiate between sex, age, size, medical history, or other characteristics of the substance-free subjects. In addition, thermal minutiae on non-substance signatures may be developed for each person enrolled in to a system who will be subsequently scanned for substance use. At the time that the thermal data is collected, urinalysis or blood testing can be performed to assure that the subject is substance-free.

Subsequently, each time a person enrolled in the

proach involves sampling the thermal waveforms and producing a matrix of values. where one dimension of the matrix is the number of minutiae used. and the other is the number of temperature samples over time. The reference library can include wider matrices. involving longer time period than is practical for an operational screening system. The comparison between the collected matrix and the reference matrix would use a digital shifting and difference calculation to find the best area of match.

A measure of goodness of match is made between the collected thermal signatures and the signatures for each substance under each protocol in the library. The system manager selects a threshold to be applied to each comparison, such that matches which are closer than that threshold will cause the system to issue a notice of possible substance detection.

The results of comparison with the different markers may be recorded or stored or output to decision markers. Alternatively. thresholds may be automatically applied to the calculated differences to render a pass/fail or clean/under-influence determination. The statistical estimate of confidence in the determination can also be presented.

The apparatus for drug and alcohol detection is shown in Fig. 18. Three primary functions are performed with the apparatus: Enrollment, Reference Signatures Development, and Screening. System components may in general be rendered as software. hardware, or firmware elements.

Prior to automated operation of the Identification and Detection (ID&D) system, a human operator termed a System Manager must perform set-up and initialization of the system, which he does via the System Manager Interface, which includes a monitor, keyboard, and possibly a printer and other peripherals such as a mouse which are normally associated with personal computers. A System Manager must confirm the identity of the enrollee 4, and input the associated identification information into the person identifier and condition identifier database 6 within the system processor 8. The enrollee's current and past medical history data is also input to the system, including the results of urinalysis or blood tests to detect substance use, current use of illicit substances, and other information which may bear upon alcohol and drug testing results.

The enrollee stands or sits at designated location facing the infrared camera 12 and within reach of the event trigger 14. When the event trigger is engaged by either the enrollee or System Manager. the output from the infrared camera is sampled by the frame grabber 16 and the resulting frame stored in its buffer. At the same time. the camera output is recorded on a video cassette recorder 18 which incorporates annotation of the date time. location. and identify of the enrollee.

The image in the frame grabber and buffer is processed by the face locator 20 which determines that the image includes a single face which is in focus and of a suitable size and position. If the image is not suitable according to software criteria established within the face locator, a new image frame is grabbed and the process repeated until a suitable image is obtained.

The image is then processed by the minutiae extractor and identifier 22 which locates the SIMCOS minutiae points and extracts their positions on the image and the corresponding apparent temperatures. Additional frames are grabbed and processed for a period of time selected by the system manager.

The extracted minutiae locations and corresponding temperatures are processed by the thermal signature extractor 24 which generates for each minutiae point the thermal variation over time. For enrollment purposes, a single frame may suffice. However. multiple frames over a period of seconds should be taken in order to help calibrate and factor-out noise in the system.

Personal data about the enrollee is transferred to the enrollment database 26, along with the thermal signatures extracted for the enrollee. If the enrollee is known to be substance-free, the thermal signatures are also transferred to the substance-free signature database 28 stored by enrollee and also to the substance-free thermal signature database stored by classification of enrollee 30.

If the enrollee is known or found to be substance-influenced. the thermal signatures are instead transferred to the substance-related thermal signature database stored by substance and also to the substance-related thermal signature database stored by protocol 34. The definitions of protocols will relate to clinical trial used for developing reference thermal signatures. and may also include self-reporting classifications such as "heavy" regular user of cocaine". or "infrequent user of marijuana but not within the past month

The extracted thermal signatures of the enrollee are also transferred to the thermal signature comparator and statistical analyser 36 which compares the signatures of the enrollee with other signatures in the databases. If the enrollee's signatures vary too much from the others in the same substance-free class or from others in the same substance-related or protocol-related databases. then the system manager may request review by the medical review officer 38 prior to including the enrollee's data in the database.

If no anomaly is detected in the [illegible]'s thermal signature, then the enrollee is instruct[illegible] to how to activate the system for future access [illegible]ening. If a personal identification number is to b[illegible] that PIN will be assigned. If voice recognition [illegible] or other technique for identification is to be us[illegible] procedures will be taught. The enrollee is n[illegible]ed in the system.

The substance use identification [illegible]on system requires databases of thermal si[illegible] sub-stance-free and substance-related in[illegible] clinical trials in which substances are a[illegible] under rigorous protocols. the same appara[illegible]ed to

grant access through manual intervention or through automatic control of an access portal. Depending upon the particular classification selected, or the amount of variation between the entrant and the selected reference signatures, the result classification may be sent either automatically or through manual intervention to a medical review officer 40 for a final determination. The entrant's file from the enrollment database 26 is also sent to the MRO to provide background information.

Statistical analysis of drug or alcohol use within a random population is also encompassed by the present invention. This is performed by scanning a crowd and locating faces therein for analysis.

Various standard methods for locating faces in an image frame can be used. A particularly useful approach uses an ellipse detector to find relatively warm ellipses (thermal faces) within a relatively cool background. The ellipse is located within the expected height range for humans, the detected temperature is within the expected range for human faces, and characteristics common to all facial thermograms (hot canthi regions, symmetry of the eyes, nostrils, ears, cheeks, etc.) are not violated. Each detected face in each frame is evaluated to determine if it meets the quality requirements for further processing. Requirements include the facial image being in focus, being large enough to provide adequate resolution of the facial minutiae, being oriented close enough to full face forward and being free enough of blockages including beards, eyeglasses, and intervening obstructions, such that a sufficient number of facial minutiae can be extracted from the facial image. The specific requirements are dependent upon what substances are to be detected, in how small a dose, and after what period of time. Faces which do not meet the quality requirement are not further considered. Those which are qualified are assigned unique tags.

The next frame is then processed and quality faces are detected as above. Each such face is then compared to the faces in the previous frame, or to those faces from the previous frame which are close enough in location that they could be a particular face in the current frame. Matching is performed using the facial minutiae matching method. If a current and prior face are determined to be the same, then they are given the same tag. This process continues with subsequent frames being likewise analyzed. In general, a particular tagged face will move across and then out of the field of view. When the face is no longer seen by the camera then the thermal signatures associated with each of its minutiae in each of the frames are combined and matched against a reference database for non-substance and substance-related signatures.

The system is designed for stand-alone operation. IT is deployable for programmable periods of time, during which it will analyze and classify each face which appears within its field of view. The system will not routinely record or store the thermal images, although provisions are made to do that during testing and evaluation of the system in order to allow for improvements to be made in the system and compared with earlier results. The output from the system will be graphical results such as shown in Fig. 19. The cumulative detection index of the y-axis represents the number of persons who the system estimates have used marijuana, cocaine, or heroin in an amount and within a timeframe which results in a residual level indicated by the x-axis value at the time of the analysis. The x-axis represents the confidence level of drug signature indication, which is related to the detection precision of the testing and analysis procedures. Separate curves indicate the specific drugs detected, and a composite survey indicates detection of any of the substances. Due to the frequent use of combinations of drugs, the composite curve is expected to be more significant than its components.

The system is tested using known populations of drug users, and its results compared to urinalysis results. The comparison is used to select thresholds for system decisions on classification of thermal signatures. The system can be deployed within a high intensity drug trafficking area, and its results compared to other current estimates of drug usage in that area.

The apparatus for statistical analysis is shown in Fig. 20. Three primary functions are performed with the apparatus: face acquisition and tagging; face analysis and classification; and statistical population analysis.

An infrared camera 42 is positioned such that persons in the population to be scanned generally enter, transverse, and exit the camera's field of view 44. The infrared camera produces a sequence of frames using either direct digital output or frame-grabbed video output 46, which is stored in the frame buffer storage 48. Processing of the imagery is initiated by an initializer mechanism 50 which may be a proximity detector, motion detector, or other sensor used to detect the possible presence of humans within the field of view.

The system processor 52 is comprised of five components. The face locator 54 applies rules to the buffer stored image to identify all faces in the frame. The face quality check 22 applies additional rules to determine if a given face provides sufficient information in terms of focus, resolution, position, and number of minutiae available. Each qualified face is tagged and then compared with qualified faces in the preceding frame, using the SIMCOS technique, to determine which faces have already been seen and tagged.

Faces which are seen in a given frame may have been temporarily blocked in the previous frames, and so any face may be blocked, turned, or otherwise unqualified part of the time. Comparison against earlier qualified faces is continued for a period of time which is considered a reasonable maximum time for transversing the filed of view. The face tracker 54 reassigns tags so that the same face receives the same tag in subsequent frames. There are two reasons to be concerned about consistently applying the same tag to each face. First, drug and alcohol detection accuracy improves

visual characteristics are thermal characteristics

8. A system as defined in claim 7, wherein said minutiae are limited to those in the face of the individual

9. A method for classifying an individual, comprising the steps of

(a) sensing characteristics of the individual;

(b) producing a normalized representation of the individual in response to the sensed characteristics thereof;

(c) identifying minutiae of the individual in response to the normalized representation, said minutiae corresponding to specific branch points of blood vessels of the individual;

(d) determining a correspondence between a grid of cells and the normalized representation; and

(e) classifying the individual in response to co-location of at least one of said minutiae and at least one of said cells, thereby identifying the individual as corresponding to a class.

10. A method as defined in claim 9, wherein said classifying step includes encoding the identity of the individual using a plurality of bits each corresponding to one of said cells, setting one of the plurality of bits to a first state in response to the presence in a corresponding cell of one of said minutiae and to a second state in response to the absence in the corresponding cell of any of said minutiae.

11. A non-invasive method for identifying medical patients, comprising the steps of

(a) identifying minutiae on the body of a known patient, said minutiae corresponding with branch points of blood vessels;

(b) storing a collection of minutiae data characteristics of the minutiae for the known patient in a memory to define a reference collection, said reference collection being unique to the known patient;

(c) sampling the minutiae data of an unknown patient in a selected location of the unknown patient's body to define a sample collection;

(d) comparing said sample collection with said reference collection, whereby the identity of the unknown patient can be confirmed when said sample and reference collections correspond;

12. A method as defined in claim 11, and further comprising the steps of

(e) detecting any changes in said sample pattern with respect to said reference collection, and

(f) analyzing the changes to diagnose the occurrence of a medical event in the patient.

13. A non-invasive method for diagnosing a medical condition in an individual, comprising the steps of

(a) establishing a reference collection of series of time-varying minutiae data corresponding with a plurality of known medical conditions, respectively, said minutiae data being derived from characteristics of minutiae associated with branch points of blood vessels in a human being;

(b) generating time-varying minutiae data from the individual having an unknown medical condition; and

(c) correlating said generated minutiae data with said reference minutiae data to diagnose the medical condition when a match between said generated and reference data is obtained.

14. Apparatus for identifying the use of a substance such as alcohol and drugs by an individual comprising

(a) means for identifying minutiae data in the face of the individual which are responsive to the ingestion of a substance by the individual, said minutiae data being derived from characteristics of minutiae associated with branch points of blood vessels of the individual;

(b) minutiae data generator means for generating a first collection of minutiae data of a substance-free individual and a plurality of second collections of minutiae data of an individual after the ingestion of a plurality of different known substances;

(c) means for storing said first and second collections of minutiae data in a database; and

(d) means for comparing a subsequent collection of minutiae data of an individual with said first and second collections to determine whether the individual is substance free and to determine what substance the individual has ingested where the individual is not substance-free.

responding therewith, respectively. whereby a plurality of collections are generated, one for each individual in the random population.

25. A method for determining what portion of a random population has ingested a substance such as drugs and alcohol. comprising the steps of

(a) generating a plurality reference collections of minutiae data corresponding with substance-free and substance-affected individuals :

(b) generating current collections of minutiae data for individuals in the random population, respectively: and

(c) comparing said current collections of minutiae data with said reference collections of minutiae data in order to determine the portion of the random population that is substance-free and the portion of the random population that is substance-affected.

26. A method as defined in claim 25. wherein said reference collection of minutiae data include different patterns corresponding with known ingested substances, whereby the portion of the random population which has ingested each known substance can be identified.

27. A method for annotating an image of the human body comprising the steps of ,

(a) generating an image of the human body with an infrared camera: and

(b) superimposing on said image the location of minutiae detected by said camera, said minutiae corresponding to specific branch points of blood vessels of the body.

28. A method as defined in claim 27, and further comprising the step of identifying particular minutiae to serve as reference points.

29. A method as defined in claim 27, and further comprising the steps of generating a medical image of the human body and annotating the medical image with said minutiae.

30. A method as defined in claim 29, and further comprising the step of identifying particular minutiae to serve as reference points.

31. Apparatus for annotating an image of the human body, comprising

(a) means for generating an infrared image of the body:

(b) means for generating a pattern of minutiae from said infrared image. said minutiae corresponding with specific branch points of blood vessels of the body:

(c) means for generating a medical image of the body: and

(d) means for annotating said pattern of minutiae on to said medical image.

32. A method for maintaining the position of a surgical instrument relative to a surgical site during a surgical procedure, comprising the steps of

(a) identifying minutiae in the vicinity of a surgical site on a patient, said minutiae corresponding with specific branch points of blood vessels of the patient:

(b) generating a reference minutiae pattern for a stationary patient:

(c) generating a reference position of a surgical instrument with respect to said reference pattern:

(d) detecting deviations from said reference pattern owing to movement of the patient and from said instrument reference position owing to displacement ofthe instrument: and

(e) repositioning the instrument with respect to said reference pattern to accurately position the instrument at the surgical site.

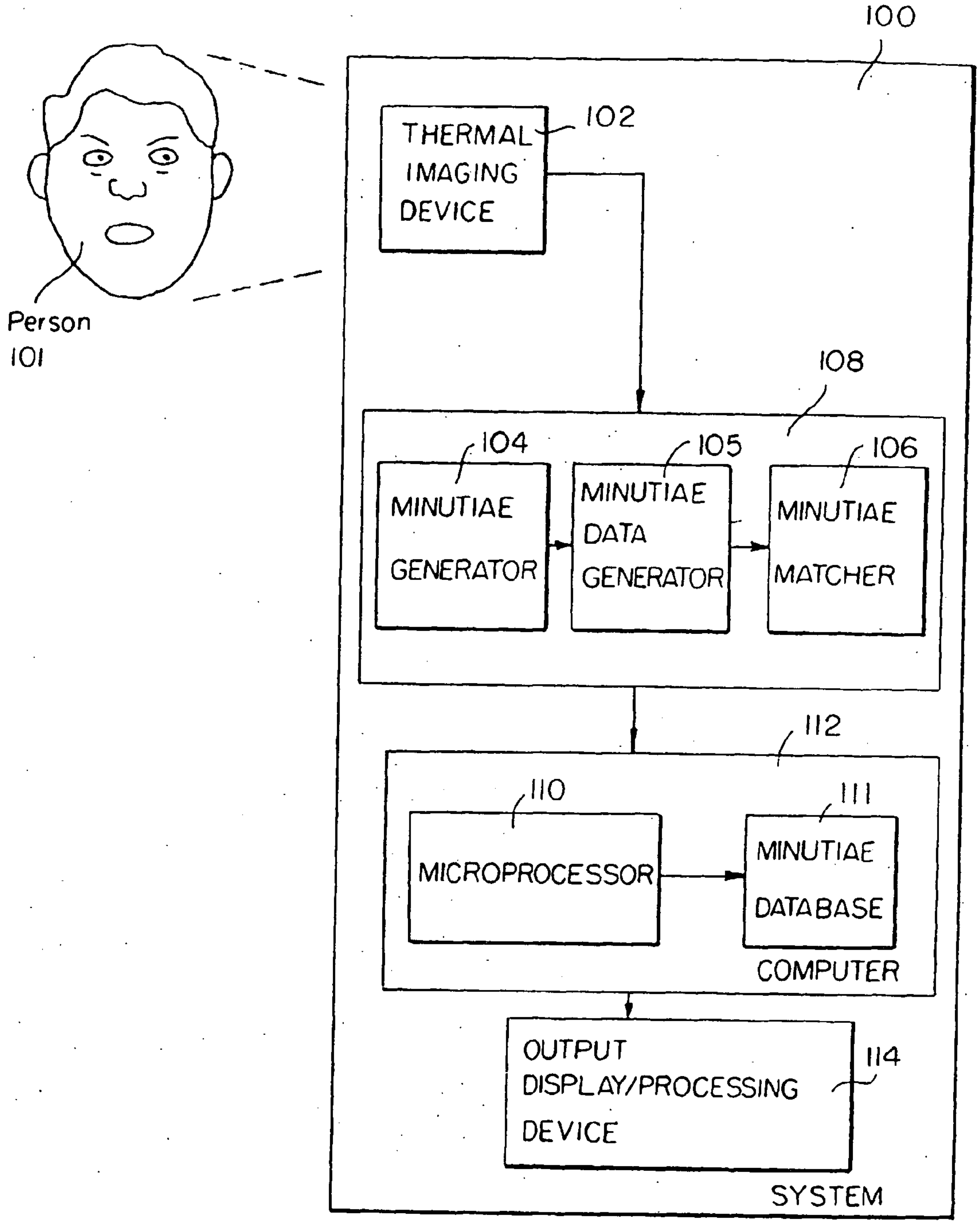
33. Apparatus for maintaining the position of a surgical instrument relative to a surgical site during a surgical procedure, comprising

(a) means for identifying minutiae in the vicinity of a surgical site on a patient, said minutiae corresponding with specific branch points of blood vessels of the patient:

(b) means for generating a reference minutiae pattern for a stationary patient:

(c) means for generating a reference position of a surgical instrument with respect to said reference pattern:

(d) means for detecting deviations from said reference pattern owing to movement of the patient and from said instrument reference position owing to displacement of the instrument.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THERMAL IMAGING DEVICE
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101
108
MINUTIAE GENERATOR
104
MINUTIAE DATA GENERATOR
105
MINUTIAE MATCHER
106
112
MICROPROCESSOR
110
MINUTIAE DATABASE
111
COMPUTER
OUTPUT DISPLAY/PROCESSING DEVICE
114
SYSTEM

FIG. 1

Arteries to Brain: Schema

FIG. 2c

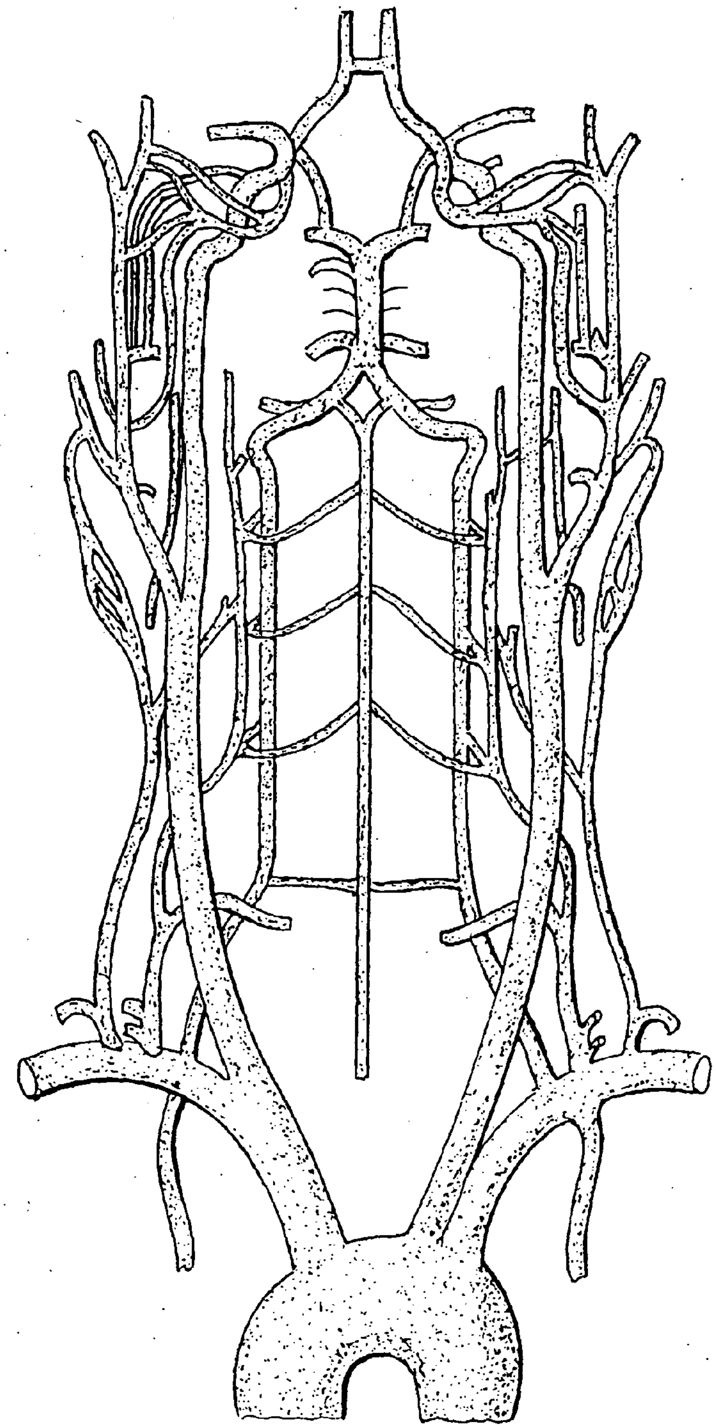
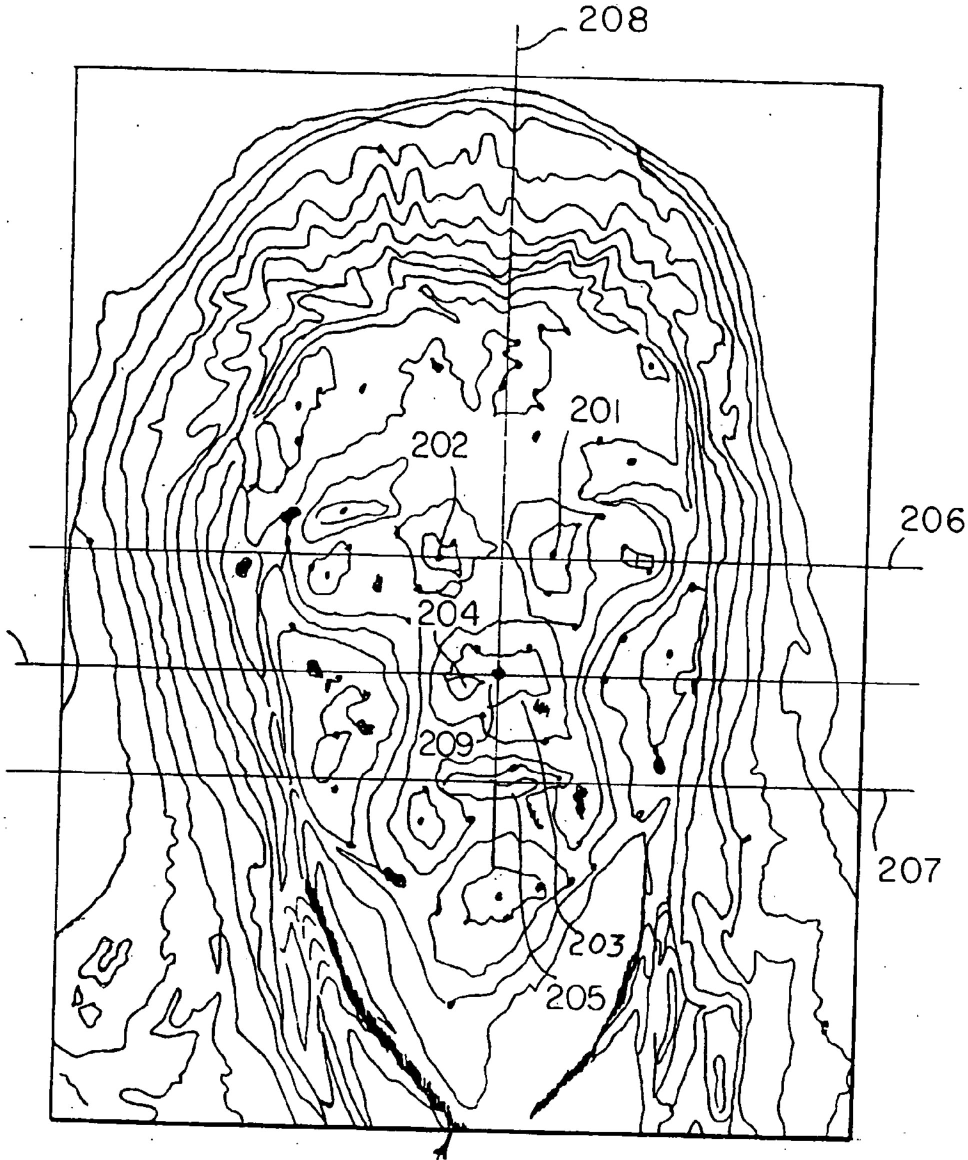


FIG. 4



Facial Thermogram 200

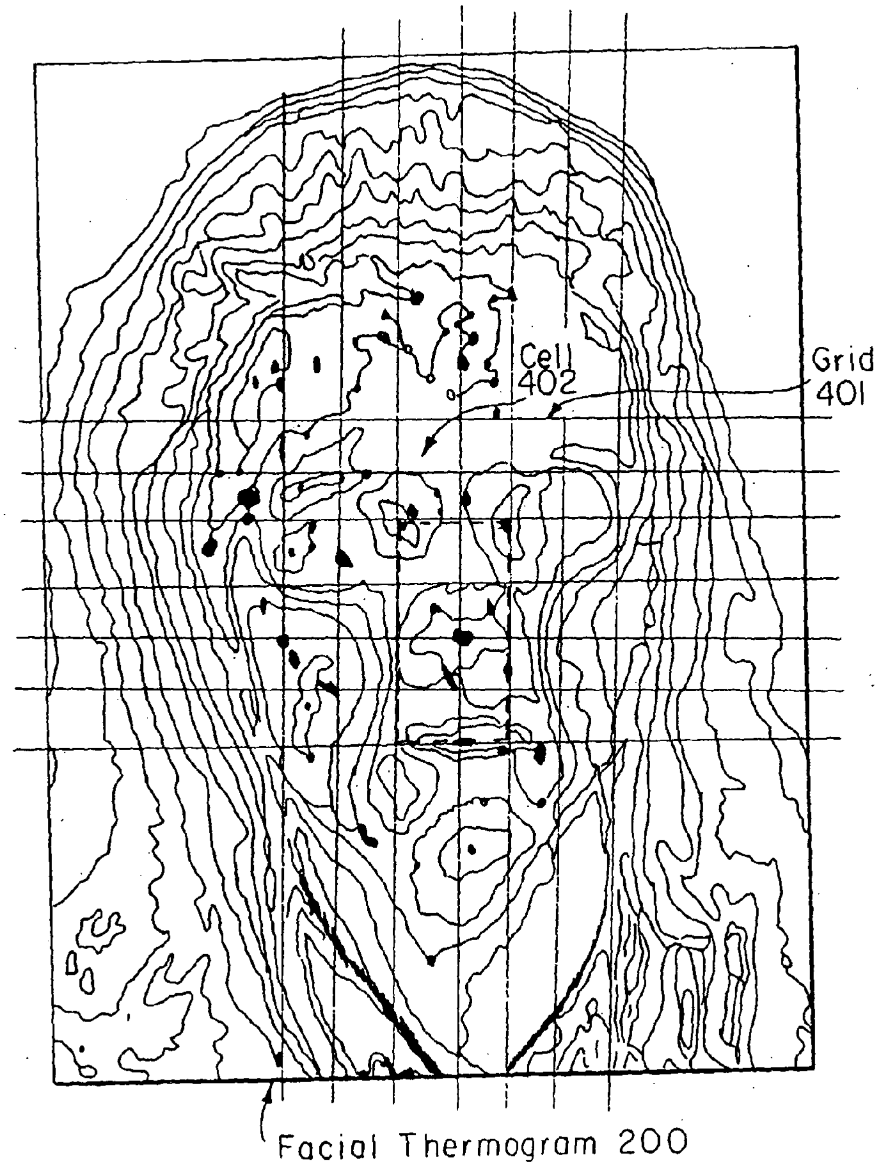
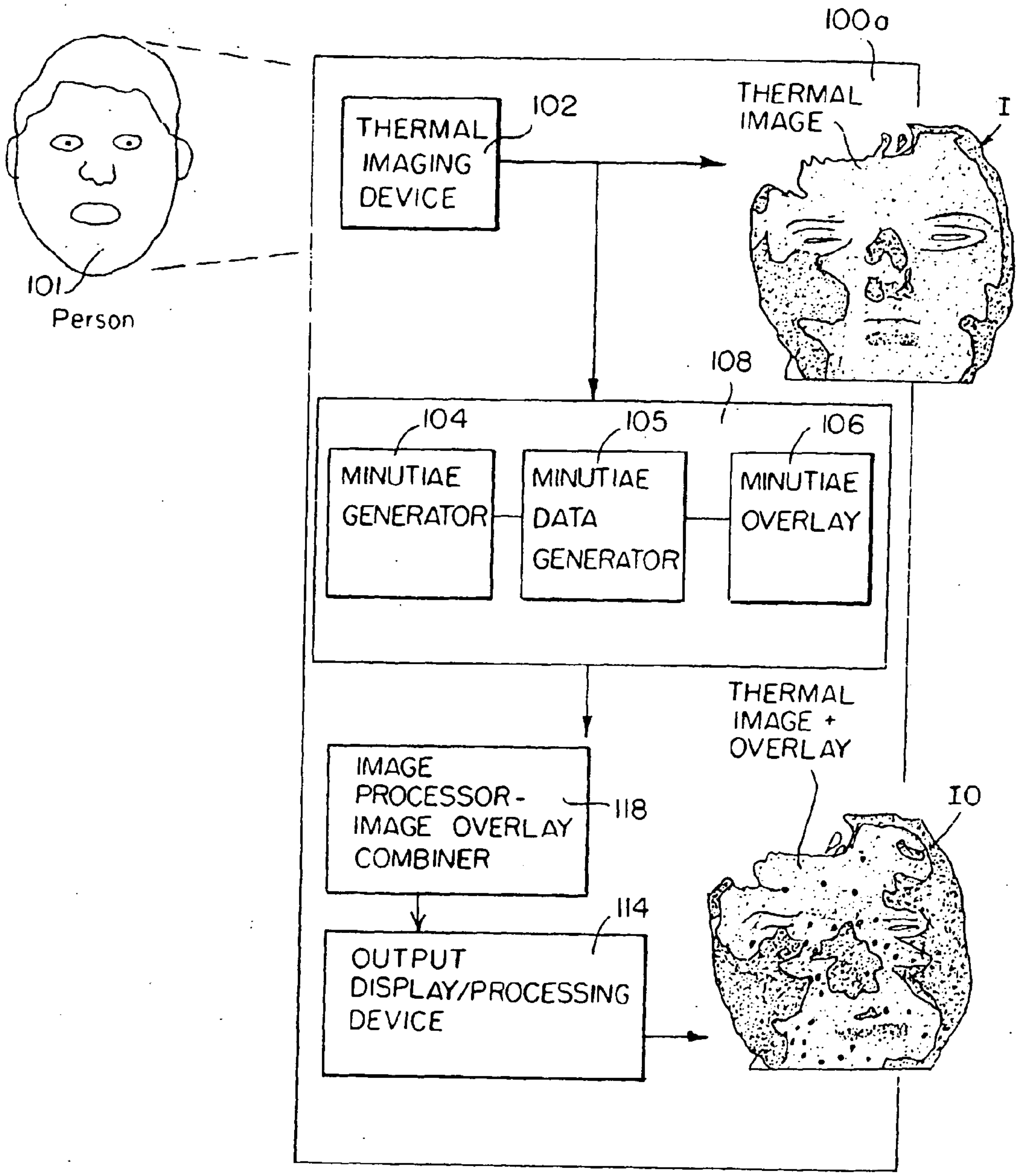


FIG. 6



100a
THERMAL IMAGING DEVICE
102
THERMAL IMAGE
I
101
Person
108
104
MINUTIAE GENERATOR
105
MINUTIAE DATA GENERATOR
106
MINUTIAE OVERLAY
THERMAL IMAGE + OVERLAY
IMAGE PROCESSOR-IMAGE OVERLAY COMBINER
118
IO
114
OUTPUT DISPLAY/PROCESSING DEVICE

FIG. 8

FACIAL THERMAL MINUTIAE

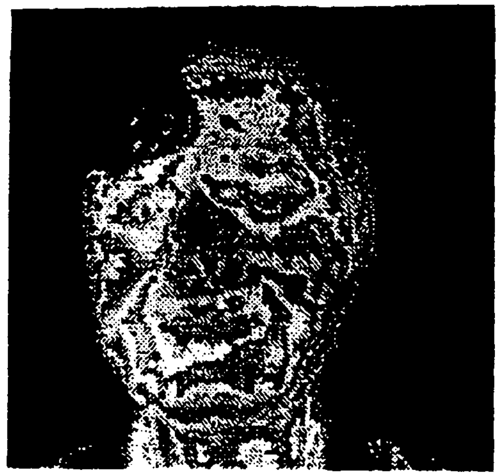


FIG.10a

FIG.10b

FIG.10c

FIG. 12

THERMAL CHEST IMAGE FROM FIFTEEN FEET

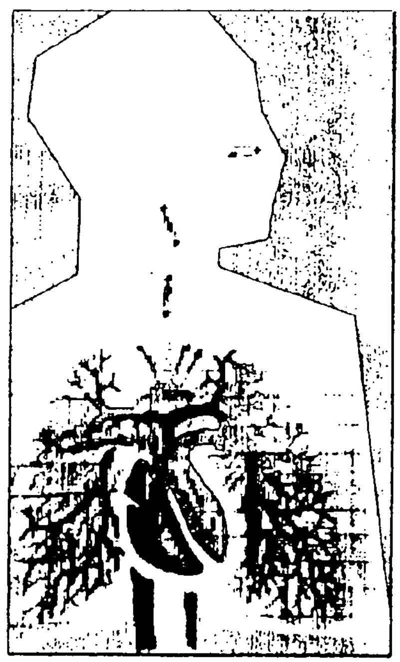


FIG. 13

Fran before and after alcohol

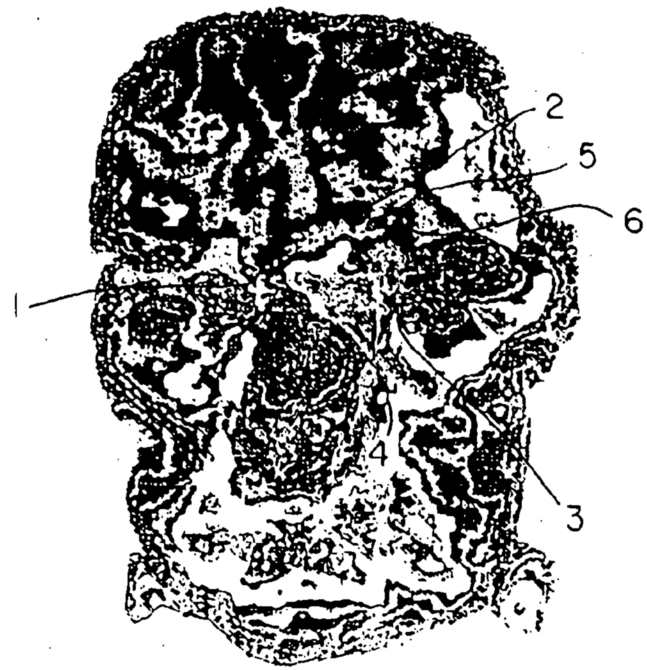


FIG.15

THERMAL MINUTIAE

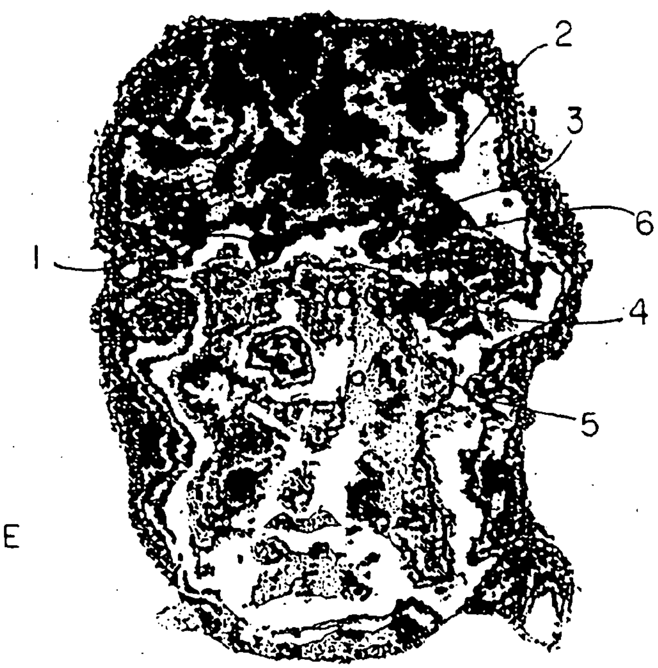
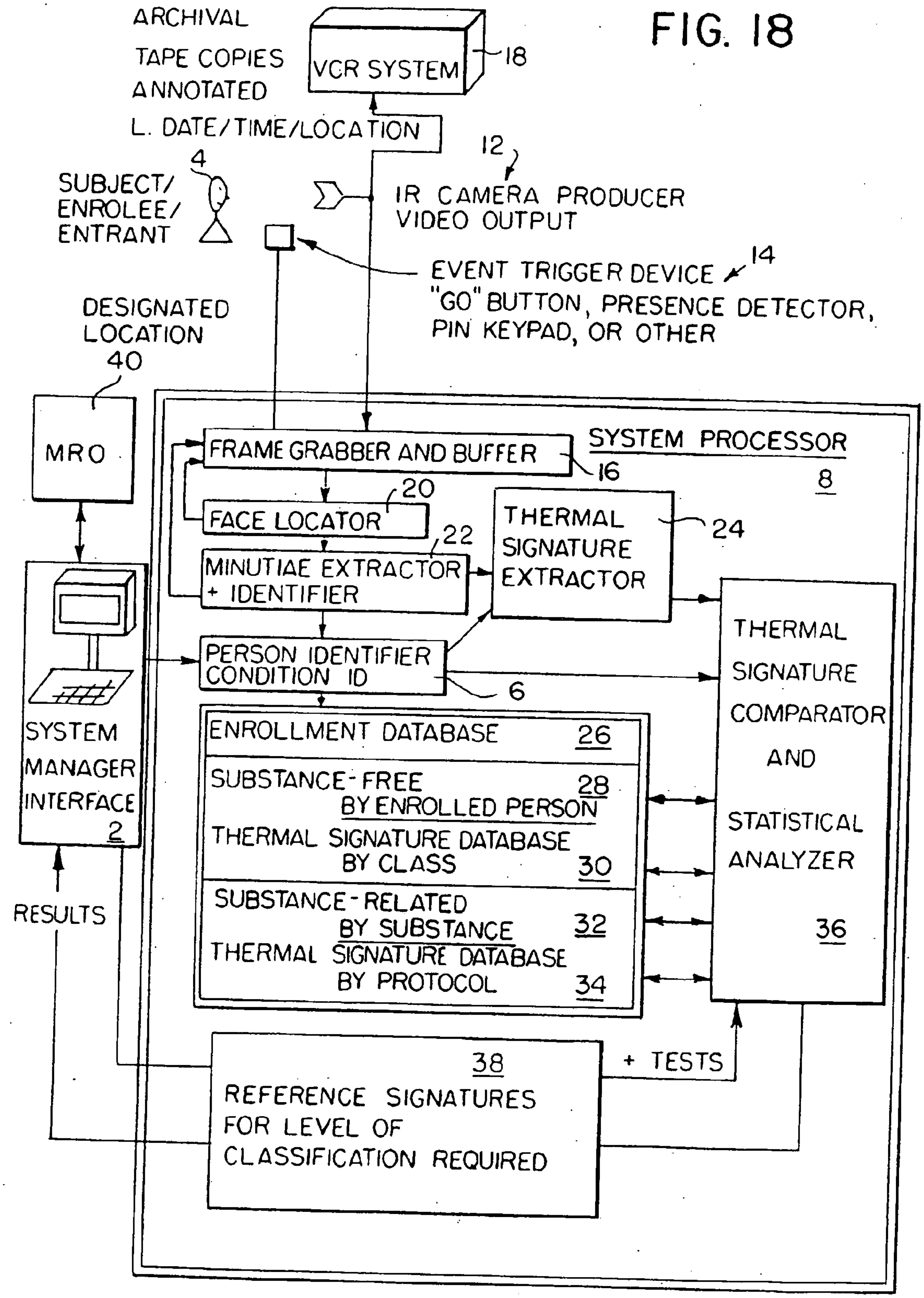


FIG.16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ANNOTATED
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VCR SYSTEM
18
12
SUBJECT/
ENROLEE/
ENTRANT
4
IR CAMERA PRODUCER
VIDEO OUTPUT
EVENT TRIGGER DEVICE
14
"GO" BUTTON, PRESENCE DETECTOR,
PIN KEYPAD, OR OTHER
DESIGNATED
LOCATION
40
MRO
FRAME GRABBER AND BUFFER
16
SYSTEM PROCESSOR
8
FACE LOCATOR
20
THERMAL
SIGNATURE
EXTRACTOR
24
MINUTIAE EXTRACTOR
+ IDENTIFIER
22
PERSON IDENTIFIER
CONDITION ID
6
THERMAL
SIGNATURE
COMPARATOR
AND
STATISTICAL
ANALYZER
36
SYSTEM
MANAGER
INTERFACE
2
ENROLLMENT DATABASE
26
SUBSTANCE-FREE
BY ENROLLED PERSON
28
THERMAL SIGNATURE DATABASE
BY CLASS
30
SUBSTANCE-RELATED
BY SUBSTANCE
32
THERMAL SIGNATURE DATABASE
BY PROTOCOL
34
RESULTS
38
REFERENCE SIGNATURES
FOR LEVEL OF
CLASSIFICATION REQUIRED
+ TESTS

FIG. 18

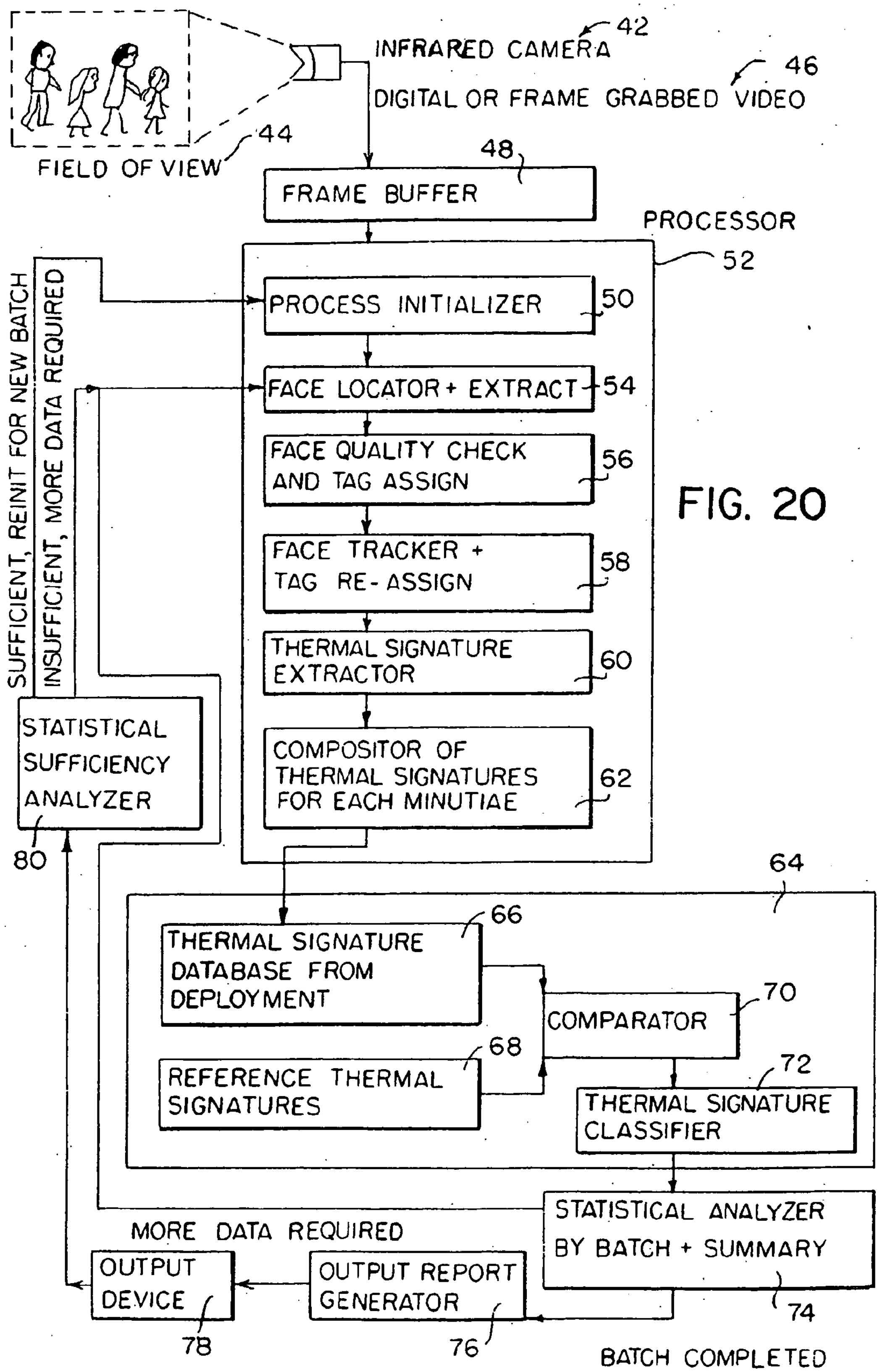
INFRARED CAMERA
42
46
DIGITAL OR FRAME GRABBED VIDEO
44
FIELD OF VIEW
48
FRAME BUFFER
PROCESSOR
52
PROCESS INITIALIZER
50
FACE LOCATOR + EXTRACT
54
FACE QUALITY CHECK AND TAG ASSIGN
56
FACE TRACKER + TAG RE-ASSIGN
58
THERMAL SIGNATURE EXTRACTOR
60
COMPOSITOR OF THERMAL SIGNATURES FOR EACH MINUTIAE
62
SUFFICIENT, REINIT FOR NEW BATCH
INSUFFICIENT, MORE DATA REQUIRED
STATISTICAL SUFFICIENCY ANALYZER
80
64
THERMAL SIGNATURE DATABASE FROM DEPLOYMENT
66
COMPARATOR
70
REFERENCE THERMAL SIGNATURES
68
THERMAL SIGNATURE CLASSIFIER
72
STATISTICAL ANALYZER BY BATCH + SUMMARY
74
MORE DATA REQUIRED
OUTPUT DEVICE
78
OUTPUT REPORT GENERATOR
76
BATCH COMPLETED

FIG. 20

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(71) Applicant: Prokoski, Francine J.
Fairfax, Virginia 22030 (US)

(72) Inventor: Prokoski, Francine J.
Fairfax, Virginia 22030 (US)

(74) Representative: Ablett, Graham Keith et al
Ablett & Stebbing,
Caparo House,
101-103 Baker Street
London W1M 1FD (GB)

(54) **Method and apparatus for annotation of medical imagery to facilitate patient identification, diagnosis and treatment**

(57) A method and apparatus for annotation of medical imagery to facilitate patient identification. diagnosis. and treatment is characterized by an imaging device for producing a first signal representative of sensed characteristics of the individual and a minutiae generator which receives the first signal and produces a second signal representative of minutiae of the individual. the minutiae corresponding to specific branch points of blood vessels of the individual A minutiae data generator analyzes the characteristics of minutiae and produces a third signal representative of the characteristics which is stored in a minutiae database for each of the plurality of known individuals and their medical conditions. The minutiae and minutiae data may be used to annotate medical imagery to facilitate subsequent image comparison by providing standardized registration points and time-varying characteristics. A minutiae matcher pairs corresponding second signals and third signals from a current patient with those from a database record. and the paired signals are used to align the images and compare them. The minutiae analysis techniques of the invention can be used to identify medical patients. assist in the diagnosis of medical conditions. and detect and monitor the use of alcohol and drugs. including anesthesia.

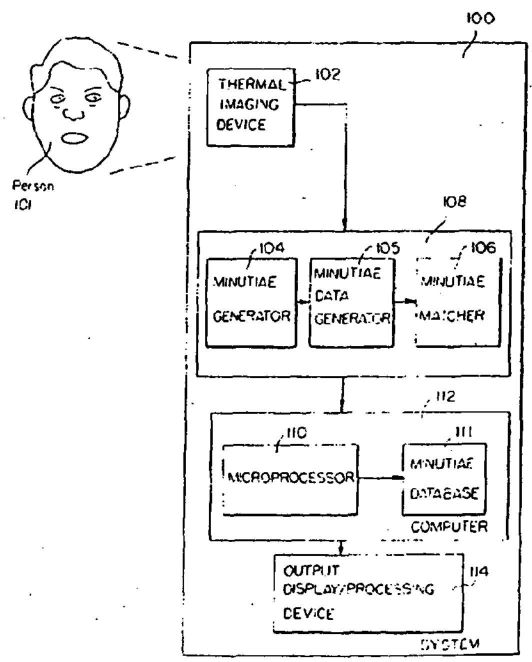

FIG. 1

EP 0 867 830 A3

European Patent Office

Application Number
EP 98 30 2267

CLAIMS INCURRING FEES

The present European patent application comprised at the time of filing more than ten claims.

☐ Only part of the claims have been paid within the prescribed time limit. The present European search report has been drawn up for the first ten claims and for those claims for which claims fees have been paid, namely claim(s):

☐ No claims fees have been paid within the prescribed time limit. The present European search report has been drawn up for the first ten claims.

LACK OF UNITY OF INVENTION

The Search Division considers that the present European patent application does not comply with the requirements of unity of invention and relates to several inventions or groups of inventions, namely:

see sheet B

☒ All further search fees have been paid within the fixed time limit. The present European search report has been drawn up for all claims.

☐ As all searchable claims could be searched without effort justifying an additional fee, the Search Division did not invite payment of any additional fee.

☐ Only part of the further search fees have been paid within the fixed time limit. The present European search report has been drawn up for those parts of the European patent application which relate to the inventions in respect of which search fees have been paid, namely claims:

☐ None of the further search fees have been paid within the fixed time limit. The present European search report has been drawn up for those parts of the European patent application which relate to the invention first mentioned in the claims, namely claims:

European Patent Office

LACK OF UNITY OF INVENTION SHEET B

Application Number
EP 98 30 2267

The Search Division considers that the present European patent application does not comply with the requirements of unity of invention and relates to several inventions or groups of inventions, namely:

1. Claims: 1-12

   Classification or identification of persons based on features relating to bloodvessel patterns

2. Claims: 13-26

   Diagnosing a condition of a person or persons based on bloodvessel patterns

3. Claims: 27-33

   Using particular parts of a bloodvessel pattern as positional reference points